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Reference conditions for old-growth pine forests in the Upper West Gulf Coastal Plain

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DON C. BRAGG (U.S. Department of Agriculture, Forest Service, Southern Research Station). Reference conditions for old-growth pine forests in the Upper West Gulf Coastal Plain. J. Torrey. Bot. Soc. 129: 261–288. 2002.—Ecosystem restoration has become an important component of forest management, especially on public lands. However, determination of manageable reference conditions has lagged behind the interest. This paper presents a case study from pine-dominated forests in the Upper West Gulf Coastal Plain (UWGCP), with special emphasis on southern Arkansas. Decades of forest management, fire exclusion, exotic species invasion, and other ecological changes have converted the small remnants of mature shortleaf (*Pinus echinata* Mill.) and loblolly pine (*Pinus taeda* L.) stands into ineffectual models for restoring presettlement-like conditions. However, sufficient information can be gathered from available references to more reliably describe the boundaries of the desired reference environment. Early explorer accounts, maps, survey records, historical trade and technical publications, and modern scientific journals were consulted to reconstruct presettlement (pre-1900) forest conditions for pine-dominated landscapes of the UWGCP. On average, virgin UWGCP pine forests had considerably more shortleaf pine (especially in the uplands) than contemporary natural stands, with relatively low basal area and standing volume concentrated in large trees. Presettlement pine timber also had less uniform structural and spatial patterns than modern examples of mature pine. Assuming most of the critical processes are still present, it appears possible to recreate the compositional and structural attributes of virgin pine forests.

Key words: *Pinus*, loblolly pine, shortleaf pine, presettlement vegetation, virgin forest.

Interest in old-growth forests has increased in recent decades as issues of endangered species, wilderness, and biological and social legacies have been raised on public lands. Although millions of hectares of old-growth forests remain in the western United States, the status of eastern old-growth is more precarious. Of the nearly 154 million hectares of forestland in the eastern United States, only 798,000 hectares (approximately one-half of one percent) are primary forest (Davis 1996), with most of this concentrated in a few large tracts on public lands. Restoration of old-growth has been advocated as a means to supplement dwindling mature forests, even if the end product is not exactly equivalent to virgin timber.

Reconstructing an approximation of old-growth is not easy, however, in the highly altered ecosystems of modern North America. In addition to the lack of representative old-growth examples, new land use patterns, modified natural disturbance regimes, climate change, pollution, exotic species, extinction or extirpation of native species (or overabundance of others), and landscape fragmentation have affected the innate capacity of the environment to return to conditions similar to those prior to Euroamerican settlement. Furthermore, some sensitive old-growth-dependent species (e.g., red-cockaded woodpecker (*Picoides borealis* Vieillot)) may not survive under current forest conditions long enough to benefit from natural rates of system renewal (Bukenhofer et al. 1994). Efforts are underway to restore presettlement ecological communities using silvicultural treatments to accelerate the development of desirable stand features (e.g., Bukenhofer et al. 1994; Gaines et al. 1997; Huffman and Werner 2000). Even though these efforts cannot replace current unmanaged old-growth stands (Tyrrell 1996), managing for old-growth characteristics may permit a balance between ecologically and socially desirable conditions and some commodity production (Lennartz 1988; Guldin 1991).

Specific targets for presettlement conditions should be developed before attempting to use silvicultural manipulation to achieve old-growth-like characteristics (Trombulak 1996; Clewell and Rieger 1997; Clewell et al. 2000). Limited descriptions of old-growth forests in eastern North America have been provided from existing examples (e.g., Walker 1963; Jones et al. 1981; Cain and Shelton 1994; Harms 1996; Greenberg et al. 1997; Murphy and Nowacki 1997; Tyrrell et al. 1998; Landers and Boyer 1999). Some contemporary old-growth communities differ little from presettlement times.

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The remaining old-growth northern hardwood stands in north-central North America, for instance, are comparable to similar presettlement forests because of their remoteness and intact natural disturbance regime (wind-dominated, rather than fire). Unfortunately, most old-growth descriptions for the southeastern United States provide only limited information based on highly altered contemporary examples (White and Lloyd 1995). Thus, those engaging in ecosystem restoration have to consider other options when defining their reference conditions.

Researchers have used early land surveys to provide at least a qualitative description of presettlement vegetation (e.g., Stearns 1949; Bourdo 1956; Delcourt 1976; Schafale and Harcombe 1983; Foti and Glenn 1991; White and Mladenoff 1994; Black and Abrams 2001). Inferences also can be made by examining period photographs, paintings, sketches, or written accounts of early travelers (e.g., Nelson 1957; Hough 1965; Delcourt 1976; White 1984; Foti and Glenn 1991; Hammett 1992; Strausberg and Hough 1997). Other information sources include early technical publications, stand inventories, and current research papers (e.g., Olmsted 1902; Chapman 1912; Dickson 1991). Even old trade journals (e.g., American Lumberman) or promotional publications produced by railroads, timber companies, land speculators, or local governments can contribute to restoration efforts. For example, many large lumber companies in the southern United States were featured in trade magazines that, while emphasizing the milling, financing, and staffing of the operation, often provided photographs of virgin timberlands or individual big trees (e.g., Anonymous 1904a,b; 1905; 1906; 1909).

The U.S. Department of Agriculture, Forest Service is in the process of establishing a research project on the treatment of upland pine (*Pinus* spp.) forests for old-growth characteristics on the Crossett Experimental Forest in Ashley County, Arkansas. Most of the natural divisions of Arkansas do not have representative examples of contemporary old-growth to emulate (Pell 1981), making it necessary to find other means to identify and describe the desired ecological attributes. This work details the acquisition of reference conditions for virgin pine forests of Upper West Gulf Coastal Plain (UWGCP) using historical literature, photographs, and other relevant accounts (with special emphasis placed on southern Arkansas) to restore mature pine forests consistent with presettlement patterns.

Materials and Methods. STUDY AREA DESCRIPTION. The Gulf Coastal Plain is subdivided by the Mississippi River into East and West provinces composed of similar parent materials and geological development. The West Gulf Coastal Plain can be split further into "Upper" and "Lower" subregions based on subtle differences in elevation, parent materials, and key overstory species. Schultz (1997) distinguished the Lower West Gulf Coastal Plain (LWGCP) as level to gently rolling, fairly sandy plains below 30 m in elevation; the UWGCP included hills and plains above this level. Presettlement forests of the LWGCP were predominantly longleaf pine (*Pinus palustris* Mill.); the UWGCP was primarily shortleaf pine (*Pinus echinata* Mill.); and loblolly (*Pinus taeda* L.) was common to both subregions. The UWGCP extends west of the Mississippi River Delta from north-central Louisiana and central Arkansas (south of the Ouachita Mountains) to southeastern Oklahoma and northeastern Texas.

Although minor Holocene-era alluvial bottomlands are widespread, the UWGCP is primarily composed of marine sediments deposited during the Cretaceous and early Tertiary periods, with some areas of Pleistocene river terraces. Considerable variation in internal soil drainage can be found across the UWGCP, ranging from somewhat excessively well drained to very poorly drained, with an abundance of somewhat poorly drained sites. Soils also tend to be deep and medium textured, with relatively low nutrients and organic content (Pell 1983; Walker and Oswald 2000). Precipitation on the UWGCP averages from < 100 cm annually in Oklahoma and Texas to > 135 cm in southeastern Arkansas and central Louisiana, and the frost-free growing season length varies from 200 to 250 days (Skiles 1981; Walker and Oswald 2000). The nearby Gulf of Mexico provides moist, unstable air that may trigger extreme weather events like thunderstorms, tornadoes, hurricanes, and ice storms. Droughts are not unusual in this region (Stahle et al. 1985), and when particularly severe, widespread fires may occur. A long history of human occupation has also influenced the vegetation and disturbance patterns of the UWGCP.

HISTORICAL COVER TYPES. The expansive natural distributions of loblolly and shortleaf pine result in considerable geographic overlap between these species, although they are found locally in distinct habitats. The virgin shortleaf and loblolly pine forests that once covered millions of hectares have been reduced greatly by timber harvest, settlement, and altered disturbance regimes. Tellingly, several recent publications (e.g., Nowacki and Trianosky 1993; Gaines et al. 1997; Tyrrell et al. 1998) identifying old-growth covertypes in the eastern United States do not even list a loblolly-shortleaf pine type comparable to what once existed, possibly because there are so few examples. These forests were rarely pure pine, even in presettlement times (Harvey 1883; Mattoon 1915). Some of the most homogeneous virgin pine stands were found on fire- or overflow-prone sites (e.g., shortleaf stands in northwestern Louisiana and southwestern Arkansas (Mattoon 1915) or loblolly flatwoods in Arkansas and Texas (Mohr 1897; Forbes and Stuart 1930)).

It is also important to recognize the impact that Native Americans had on presettlement vegetation. These first inhabitants used fire, land clearing, and hunting to both directly and indirectly alter vegetation patterns for millennia before Euroamerican exploration and settlement (Forbes and Stuart 1930; Delcourt 1976; Hammett 1992; Strausberg and Hough 1997; Hamel and Buckner 1998; Key 2000). Native American use of these landscapes helped structure natural communities, but the true extent of their influence on presettlement vegetation prior to European exploration will never be adequately documented. Their decimation from disease and related upheavals starting in the 1500s fundamentally changed the dynamics of the UWGCP centuries before any chroniclers could report their impacts (Hamel and Buckner 1998; Carroll et al. 2002). The lapse of many decades between historical Native American cultures and those tribes eventually removed in the early 1800s, coupled with considerable cultural changes in native populations, also affected vegetation composition, structure, and dynamics.

MODERN VEGETATION PATTERNS. Pine, hardwood, and mixed pine-hardwood forests dominate the current natural upland communities of the UWGCP, with loblolly and shortleaf pine, oak (*Quercus* spp.), gum (*Nyssa* spp. and *Liquidambar* sp.), and hickory (*Carya* spp.) of notable importance (Foti et al. 1994; Rosson et al. 1995). Contemporary mature pine and pine-hardwood upland forests typically have a dominant pine overstory with various hardwoods, shrubs, vines, and forbs beneath them. Large regions of the UWGCP are intensively managed loblolly pine stands of both natural and planted origin. Competition control is frequently used to improve pine growth, but most managed stands still have abundant understories of oak, gum, elm (*Ulmus* spp.), maple (*Acer* spp.), greenbrier (*Smilax* spp.), honeysuckle (*Lonicera* spp.), American beautyberry (*Callicarpa americana* L.), and many other species. Most of the upland forested areas that were converted to agriculture or pastureland beginning in the middle of the 1800s have long since reverted back to even-aged pine-, oak-, and gum-dominated forests (Reynolds 1980). Very few terrace prairies and open, grassy woodlands originally found in the UWGCP remain; most were converted to rice and cotton farms or commercial forestland.

Current forest stand composition, density, and structure depend largely upon silvicultural practices. Loblolly pine and certain red oak taxa are preferred timber species, and shortleaf pine and other hardwood species are often cut to favor the more rapidly growing commodities. Stand densities are typically maintained at much higher levels than historical records suggest. Few trees are allowed to grow larger than 50 cm DBH on commercial timberlands in the UWGCP, regardless of species.

SAMPLING. Reconstruction of historical conditions depends upon the discovery and interpretation of reliable information. Scores of sources were examined for their appropriateness. Available references included accounts of early travelers and residents, original General Land Office (GLO) survey notes, historical photographs and sketches, promotional brochures, early research and technical reports, and contemporary scientific publications. Not surprisingly, most information was qualitative, but any insights that could be used in management to achieve the desired restoration goals were noted and placed in the context of other available knowledge. Many of the presettlement and contemporary pine stands cited in this work are identified in Figure 1.

Most definitions of "presettlement" and "old-growth" are at best imprecise, and at worst arbitrary assignments. Presettlement, for example, has been variously used to describe conditions before any human settlement, or the arrival of Christopher Columbus in 1492, or at the time of Native American removal and Euroamerican settlement, or before widespread commercial exploitation (e.g., Hamel and Buckner 1998). Similar uncertainty is found in old-growth delineation (Hunter and White 1997; Helms 1998).

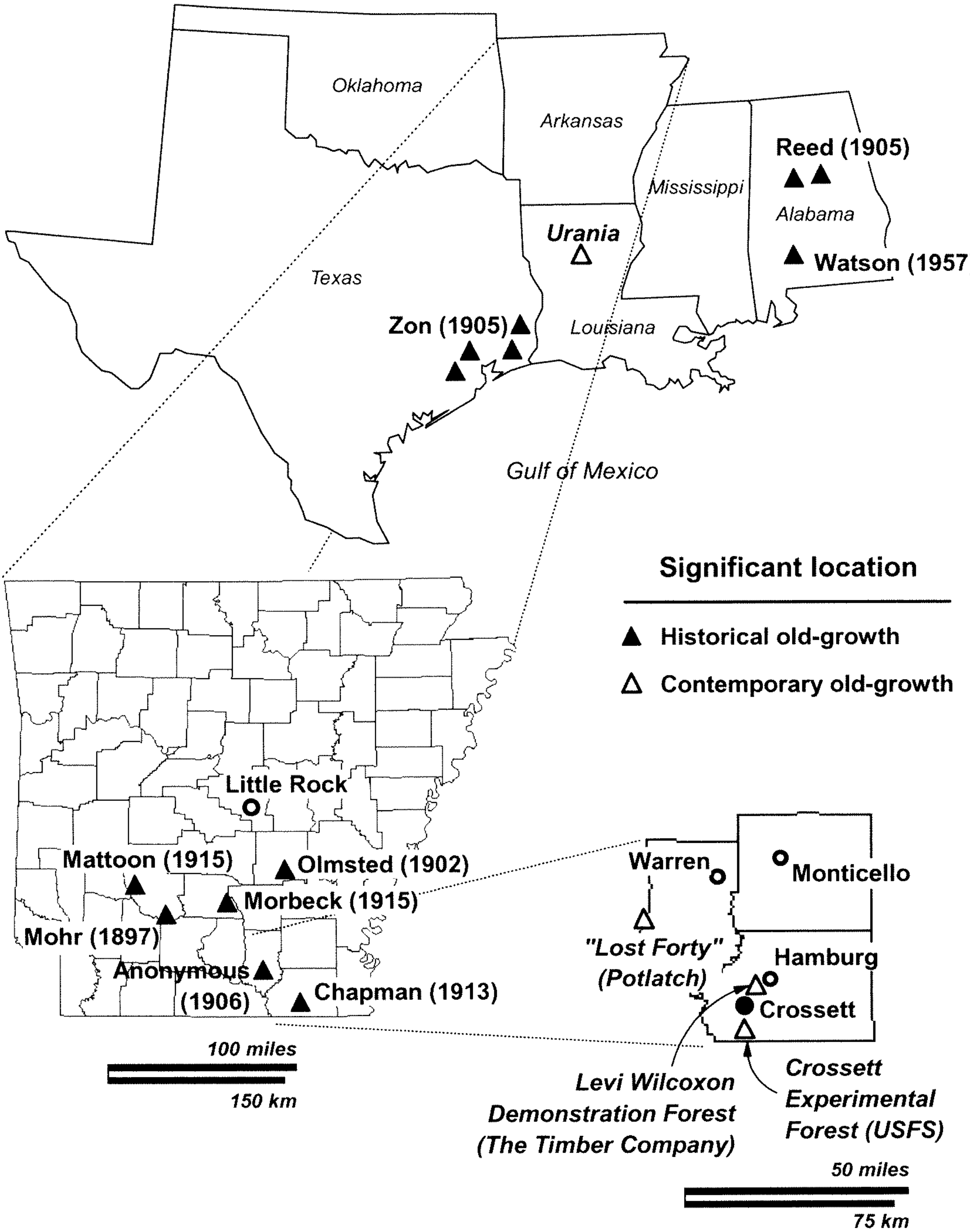

Fig. 1. Map of the Midsouth, including significant locations used in this study.

Thus, it may be most beneficial to use the era with the most reliable information that still retains the ecological integrity of early landscapes. For this study, the period from 1850 to 1900 A.D. was chosen to represent virgin forest conditions because reasonably good records can be found. Old-growth consists of relatively undisturbed stands for which the dominant trees exceed 100 years old.

Results and Discussion. Identifying Presettlement Reference Conditions. White and

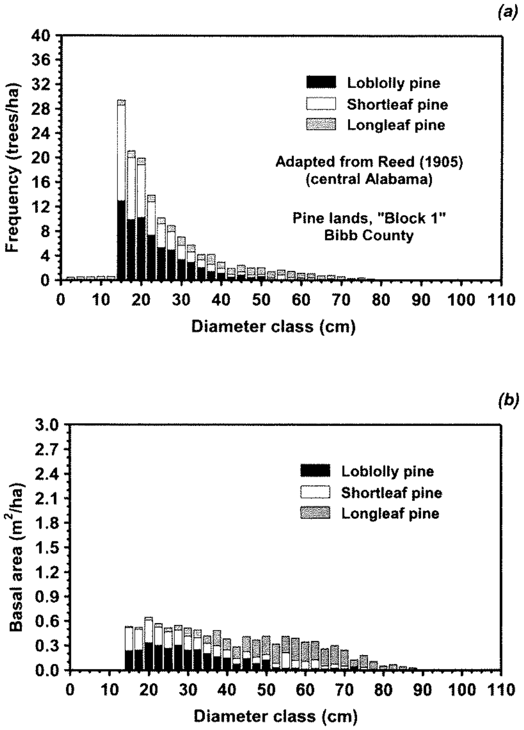

Fig. 2. Frequency *(a)* and basal area *(b)* distribution by pine species for a tract within the "pine lands" area of Bibb County, in central Alabama (adapted from Reed (1905)).

Lloyd (1995) cautioned that present-day examples of old-growth may not reflect the dynamic nature of virgin forests, and thus serve as poor models for restoration (see also Bourdo 1956). Since old-growth forests consist of more than just big or aged trees, efforts were made to quantify as many attributes of undisturbed old-growth from as close to the presettlement period as feasible. These include: species composition, size and age structure, growth performance, tree form, overstory spatial pattern, understory and forest floor conditions, disturbance regimes, degree of heart rot in live trees, and large woody debris.

Species Composition. Pine composition varied considerably in the presettlement forests of the southeast, but was usually prominent. For instance, some pinelands in Georgia were estimated to have been 89 to 99% pine (Plummer 1975). In a central Alabama mixed pine stand, Reed (1905) reported that more than 43% of the trees were loblolly pine; shortleaf pine comprised almost 39% of stems; and longleaf pine contributed 18% (Fig. 2). Reynolds et al. (1984) stated that the virgin upland forests of southern Arkansas and northern Louisiana were about 50% loblolly pine and 25% shortleaf pine, with the rest in hardwoods.

Loblolly is currently the dominant pine species in the UWGCP (Rosson et al. 1995; Schultz 1997). However, many early accounts and photographs (e.g., Fig. 3) suggest that shortleaf pine was the predominant conifer in upland virgin pine forests of southern Arkansas, northern Louisiana, and northeastern Texas (Foster 1912; Harper 1914). Loblolly pine was historically considered more of a bottomland or old field species, with shortleaf pine dominating drier or fire-prone upland sites (Mohr 1897; Reed 1905; Record 1907; Foster 1912; Chapman 1913; Mattoon 1915; Westveld 1935). Recent gains of loblolly pine at the expense of shortleaf can be partially attributed to fire exclusion, management discrimination against shortleaf, loblolly's natural colonization of old fields and clearcuts, and the widespread planting loblolly pine (White 1984; Schultz 1997).

Loblolly rarely occurred in pure stands, except in the flatwoods in Texas and southern Arkansas (Mohr 1897; Forbes and Stuart 1930). Pure shortleaf pine stands were encountered on frequently burned sites in the UWGCP (Foster 1912), although Mattoon (1915, p. 4) stated "[i]t is doubtful whether shortleaf is now found in pure type on more than from 20 to 40 per cent of its former range." A mixture of loblolly and shortleaf pine was more typical for the UWGCP. Mattoon (1915, p. 4–5) mentioned "especially heavy" stands of "complementary" shortleaf-loblolly pine in Arkansas and Louisiana, with shortleaf dominating "drier and lighter" soils and loblolly predominant on "heavier, moist soils." Zon (1905) found decidedly more loblolly than shortleaf pine in several different stands in eastern Texas (Table 1), but Hepting and Chapman (1938) described the opposite: some small (< 5 ha) old-growth remnants in Texas were predominantly shortleaf, with less than 8% of their stocking in loblolly.

Harvey (1883) noted the fraction of pine increased as one went south in Arkansas. Mohr (1897, p. 119) stated that ". . . it can be safely assumed that about one-half of the lumber cut and shipped as 'Yellow Pine' to Northern markets from southwestern Arkansas is Loblolly Pine, the other half being Shortleaf." Mohr's maps of loblolly and shortleaf pine distribution showed these species to have roughly the same stocking across much of southern Arkansas.

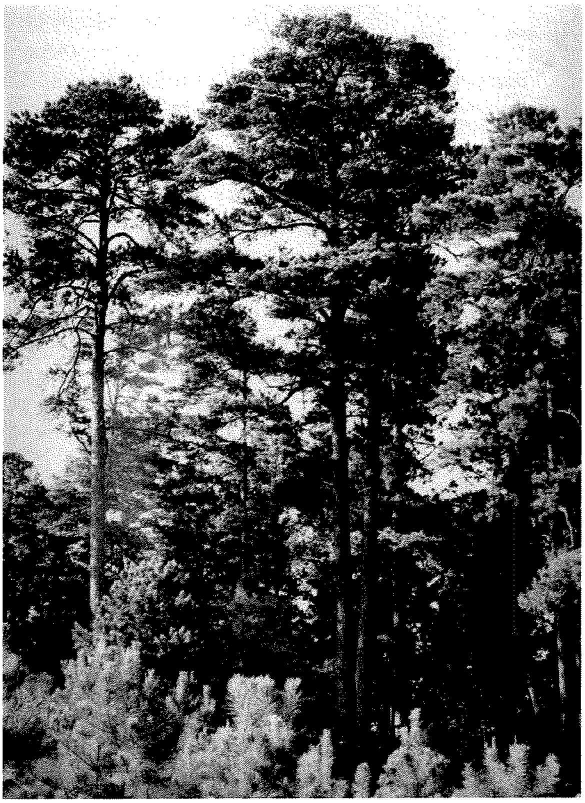

Fig. 3. The dominance of shortleaf pine in the virgin forests of UWGCP can be seen in many early photographs of the region, including this picture taken near Hamburg, Arkansas circa 1937. (Picture courtesy of the Crossett City Library.)

Near Pine Bluff, Arkansas, Olmsted (1902) reported the following abundances for shortleaf and loblolly pine for "pine ridge," "pine flat," and "hardwood bottom," respectively: 38% versus 16%; 20% versus 34%; and 2% versus 3%. Even though loblolly pine proved more abundant in two out of the three forest categories, the pine ridge type covered 80% of the 769 hectares included in the survey, compared to 12% for the pine flat and 8% for the hardwood bottom. Though not as quantitative as other estimates, Chapman (1913, p. 4) reported that the upland timber on an almost 11,000 hectare tract south of Crossett, Arkansas consisted of ". . . shortleaf and loblolly pine in almost equal mixture. . . [and]. . . form[ed] almost pure stands on all the higher lands. . . ."

Estimates of the stocking of non-pine species are far less reliable. Since most of these species were not considered valuable (Reynolds 1980), they were often excluded from early inventories (e.g., Mohr 1897; Chapman 1913). Others, while providing more information on non-pine taxa, aggregated them into broad groupings like "hardwoods" or "gum" or "white oaks" (e.g., Olmsted 1902; Reed 1905; Zon 1905; Walker 1963; Reynolds et al. 1984). Non-pine species may have constituted as little as < 1% of upland forests (Chapman 1913) to 15 to 40% of some mesic stands (Morbeck 1915) to almost every tree in some bottomland sites (Olmsted 1902; Reed 1905). Delcourt (1976) estimated from land survey records that dogwoods (*Cornus* spp.), red oaks (mostly *Quercus falcata* Michx. and *Quercus pagoda* Raf.), and post oak (*Quercus stellata* Wang.) comprised about one-quarter of the presettlement upland pine communities in northern Louisiana. The hardwoods on Arkansas Lumber Company pine lands in Bradley County were estimated to be 35% oak, 30% hickory, 25% gum, and 10% baldcypress (*Taxodium distichum* (L.) Rich.) (Anonymous 1906). Morbeck (1915) reported that white oak (*Quercus alba* L.) was the most common hardwood in many pine-dominated virgin stands near Fordyce, Arkansas, with only a limited stocking of blackgum (*Nyssa*

Table 1. Descriptions of loblolly and shortleaf pine-dominated stands from historical literature and some current examples.

General stand location Stand name	Area (ha)	Abundance			Basal area		Max. pine DBH (cm)[e]	Notes[f]
		Total (trees/ha)[a]	Shortleaf (%)[b]	Loblolly (%)[b]	Total (m²/ha)[c]	Pine (%)[d]		
HISTORICAL REFERENCES								
Gurdon, southwestern Arkansas (Mohr 1897)								
Gurdon #1	0.4	54.4	100.0	—	10.4	100.0	>63.0	1
Gurdon #2	0.4	74.1	—	<100.0	16.8	100.0	122.0	1
Ashley County, Arkansas (Chapman 1913)								
Ashley #1	16.2	50.0	~50.0[g]	~50.0[g]	13.8	100.0	>106.7	1
Ashley #2	16.2	64.9	~50.0[g]	~50.0[g]	10.9	100.0	>101.6	1
Pine Bluff, Arkansas (Olmsted 1902)								
Pine lands	706.2	203.8	35.7	18.9	14.2	65.5	91.4	2
Eastern Texas (Zon 1905)								
Stand #1	1.6	307.0	2.4	78.5	31.5	94.3	83.8	3
Stand #2	4.9	410.5	6.1	41.2	25.4	73.2	88.9	3
Eastern Texas (Garver and Miller 1933, Hepting and Chapman 1938)								
Stand #1	2.6	108.7	~92.5[g]	~7.5[g]	—	—	78.7	4
Stand #2	4.9	318.8	~92.5[g]	~7.5[g]	—	—	71.1	4
Bibb County, central Alabama (Reed 1905) (pine lands only)								
Block #1	45.3	149.6	38.6	43.4	10.4	61.5	76.2	3
CURRENT EXAMPLES								
Levi Wilcoxon Demonstration Forest, Ashley County, Arkansas (this paper)								
Main stand	6.1	387.5	5.0	13.2	31.8	57.2	92.5	5
R.R. Reynolds Research Natural Area, Ashley County, Arkansas (this paper)								
Units 41&42	32.4	414.0	1.6	17.2	34.4	54.5	91.9	5

[a] Total number of trees per hectare, including all species (if reported).
[b] Fraction of pine stems from total number of stems tallied in the stand.
[c] Total stand basal area, including all species (if reported).
[d] Fraction of pine (shortleaf + loblolly) basal area from total stand basal area.
[e] Maximum shortleaf or loblolly pine diameter (other species not included).
[f] Notes on data: 1 = values are for pines larger than 30 cm DBH, 2 = values are for all trees larger than 5 cm DBH, 3 = values are for all trees larger than 2.5 cm DBH, 4 = values are for all pines larger than 10 cm DBH, 5 = values are for all trees larger than 9 cm DBH.
[g] Composite species proportion estimates.

sylvatica Marsh.), sweetgum (*Liquidambar styraciflua* L.), hickory, and ash (*Fraxinus* spp.). In his assessment of lands south of Crossett, Chapman (1913, p. 5) found ". . . the only hardwood growth is a few very stunted and deformed oaks. . . " with "[b]etter hardwoods, including white and black oaks and some sweet gum and hickory. . . near streams where the soil is fairly well drained, moist and deep."

Contrast these historical descriptions to those of the few existing examples of old-growth pine-hardwood stands in southern Arkansas. On the proposed R.R. Reynolds RNA, loblolly pine comprised 65% of the total pine stems and 77% of total pine basal area in 1993 (Cain and Shelton 1996). Hardwoods and pine switched abundances from 1937 to 1993, with pines dropping from 80% to 20% of merchantable stems, and concurrent increases in hardwood frequency (especially during the last decade). Interestingly, the proportion of pine basal area has changed little over the 60+ year observation period of the stand, although it is anticipated that hardwoods will increase in importance in the future (Cain and Shelton 1996). The gradual replacement of intolerant pines to more shade tolerant hardwoods has been noted in other old-growth loblolly-shortleaf stands (e.g., Watson 1957; Lipps and de Selm 1969; Jones 1971; Stalter 1971; Jones et al. 1981; Fail 1991; Harrington et al. 2000).

Stand Structure and Dynamics. Tree Density and Size Class Distribution. Stand structure

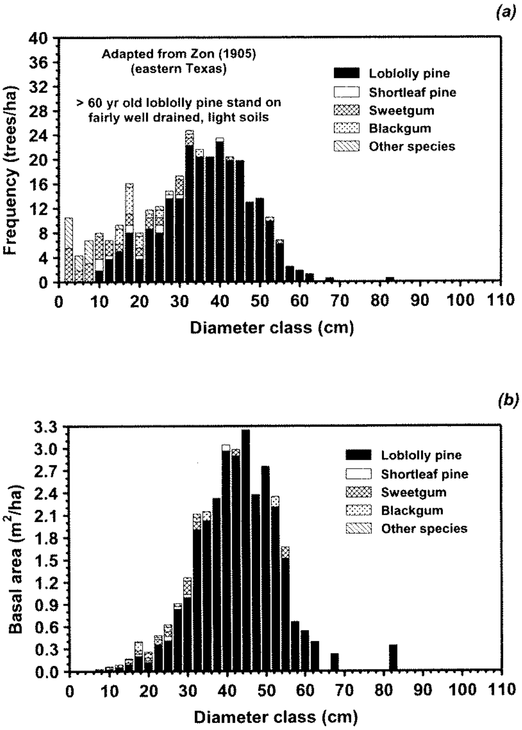

Fig. 4. Frequency *(a)* and basal area *(b)* distributions by species and diameter class for a > 60 years old loblolly pine stand in eastern Texas (adapted from Zon (1905)).

can also be reconstructed from historical data. Although open stands were more common, pine-dominated old-growth (Table 1) in the UWGCP could produce relatively high stocking and stand densities (Westveld 1935; Walker 1963). Some east Texas pine stands reported by Zon (1905) had > 300 trees/ha and stand densities > 25 m^2/ha, of which small hardwoods comprised much of the stocking and basal area. The pines in Zon's inventory were smaller (on average, < 40 cm DBH) and they showed a distinctly modal diameter distribution (Fig. 4). The stands inventoried by Zon (1905) and Reed (1905), though dominated by small diameter trees, still contained scattered large (> 70 cm DBH) individuals. Hepting and Chapman (1938) described two Texas old-growth shortleaf pine stands that averaged 109 trees/ha and 319 trees/ha greater than 10 cm DBH.

Mohr (1897, p. 96 and 119) provided summaries of an "average" acre of both shortleaf and loblolly pine near Gurdon, Arkansas (Table 1, Fig. 5). Using diameter class means for these stands, shortleaf pine stand had 54.4 trees greater than 30 cm DBH (10.4 m^2 of basal area) per hectare and loblolly pine stand averaged 74.1 trees/ha and 16.8 m^2/ha. The loblolly acre contained more stems < 45 cm DBH than large trees, while the shortleaf acre was dominated by large (> 45 cm DBH) pines. Chapman (1913) reported on uncut pine stands south of Crossett, Arkansas (Table 1). The tract in Figure 6a has a relatively even distribution of trees from 30 to 90 cm DBH, gradually tapering off by 110 cm DBH (a pattern consistent with uneven-aged old-growth stands (Smith 1986)). Although more evenly distributed than Mohr's stands, stocking was still low, with an average of 50 trees/ha and 13.8 m^2/ha in basal area (concentrated in the 55 to 85 cm DBH class range, Fig. 6a). Chapman's (1913) second stand consisted of young and mature pine with better stocking in the smaller size classes (Fig. 6b), although some very large trees were present (1.2 trees/ha > 90 cm DBH). Pines < 60 cm DBH were more abundant, but stocking (65 trees/ha) and basal area (10.9 m^2/ha) remained low.

In a stand near Pine Bluff, Arkansas, Olmsted (1902) differentiated between loblolly and shortleaf pine and tallied stems down to 5 cm DBH. Shortleaf pine dominated most size classes (Fig. 7), with its stocking in some diameter classes triple that of loblolly pine. The distribution of trees > 30 cm was similar to Chapman's inventory, except Olmsted (1902) reported no stems > 95 cm DBH. Diameter class basal area peaked at 55 cm and tapered off rapidly, with little found in trees > 85 cm DBH. Inclusion of the smaller (< 30 cm) size classes yielded 203.8 trees/ha, or about four times the stocking of Mohr's (1897) and Chapman's (1913) stands (Table 1). However, additional stocking in the smallest diameter classes did not result in higher stand density as the parcel averaged only 14.2 m^2/ha of basal area, with approximately one-quarter of the total stand basal area in trees < 30 cm DBH.

Contemporary old-growth stands almost always have greater tree density than virgin forests. A photograph taken (circa 1948) of a sign at the entrance to the Levi Wilcoxon Demonstration Forest lists some of its attributes, including an average stocking of about 193 trees/ha greater than 15 cm DBH (Johnson et al. 1994). This stand now has almost 390 stems/ha greater than 9 cm DBH, most of which are small hardwoods. The proposed R.R. Reynolds Research Natural Area on the Crossett Experimental Forest has an average stocking of 414 trees/ha and a density of 34.4 m^2/ha of basal area

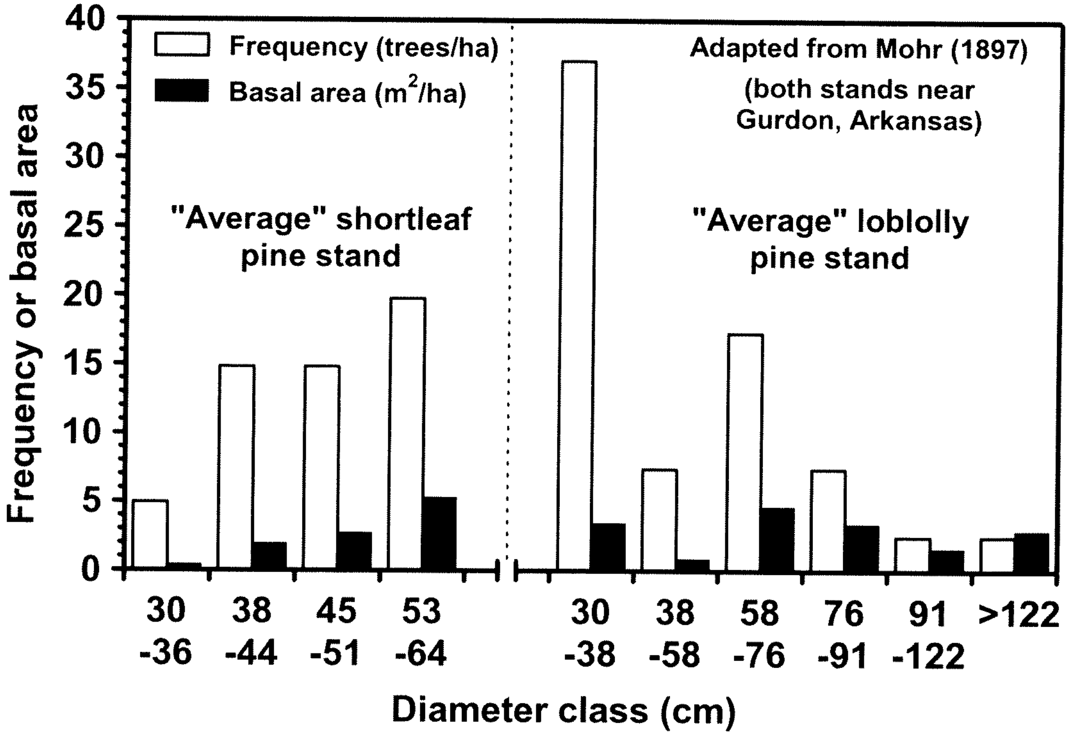

Fig. 5. Frequency and basal area distribution for "average" shortleaf and "average" loblolly pine stands near Gurdon, Arkansas (Mohr 1897).

(Table 1), with a gradually increasing representation of hardwoods (Cain and Shelton 1996; Shelton and Cain 1999).

Maximum Tree Dimensions. While never reaching the maximum dimensions of western yellow pines like ponderosa (*Pinus ponderosa* Dougl. ex Laws.), both loblolly and shortleaf pine can grow to impressive size in the UWGCP (Table 2). The biggest pines tended to grow as scattered individuals on moist, fertile bottomland sites (Record 1907). Individual loblolly pines can exceed 55 m in height (Table 2), with heights of 30 to 40 m probably typical of canopy trees in most virgin stands. Mattoon (1915) believed that 40 m was the maximum height for shortleaf pine, although canopy trees in old-growth shortleaf stands on poorer sites rarely exceed 25 m (Mattoon 1915; Fountain and Sweeney 1985; Fountain 1991). Loblolly pine also grows to larger diameters than shortleaf pine (Table 2). Pines exceeding 100 cm DBH in presettlement old-growth forests of the UWGCP were not uncommon (Chapman 1942; Reynolds et al. 1984). A review of the GLO survey notes for Ashley County, Arkansas found examples of pine (species were not distinguished) up to 183 cm in diameter, although most were < 120 cm (see also White 1984). Buckner (1979, p. 8) reported an interview with A.C. Moncrief, Sr. (a long-time employee of Crossett Lumber Company) who said the townsite of Crossett was originally in the midst of virgin pines ". . . three, four, and five feet in diameter. . . " (90 to 150 cm DBH). The Morris Pine (near Hamburg, Arkansas) was ~ 137 cm DBH when an early article about this loblolly pine was published (Anonymous 1950), and currently has a diameter of 142 cm.

With the possible exception of baldcypress and some select oak species, very little attention was given to the size of non-pine taxa. Even though most other taxa do not grow as tall as the pines, many are capable of reaching heights of 30 to 45 m. Early surveyor's records of Ashley County provide numerous examples of baldcypress, oak, and sweetgum > 125 cm DBH, especially near the bottoms of the Saline and Ouachita Rivers and Bayou Bartholomew (see also Chapman 1913). Reynolds et al. (1984) noted that hardwoods > 60 cm DBH were common in the virgin pine forests of southern Arkansas and northern Louisiana. Early trade journals of-

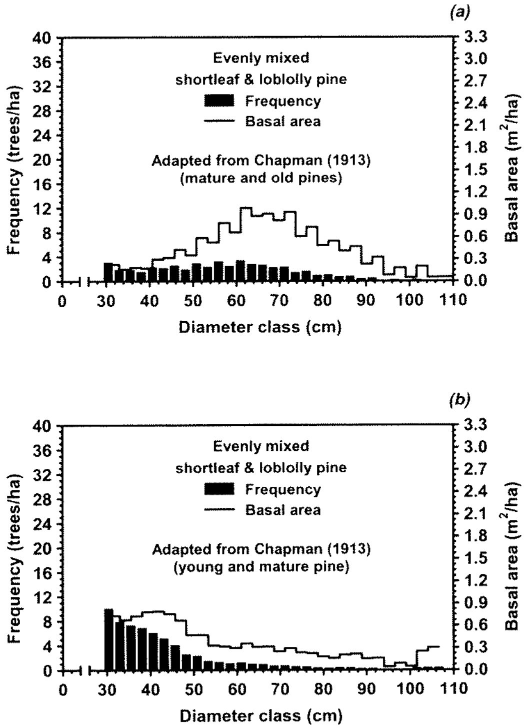

Fig. 6. Frequency and basal area distribution for mixed shortleaf and loblolly pine stands south of Crossett, Arkansas (Chapman 1913). Chapman did not sample trees < 30 cm DBH.

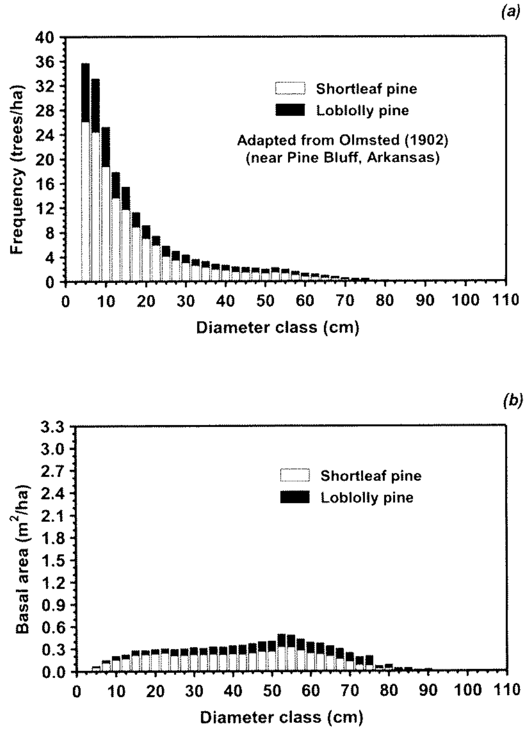

Fig. 7. Frequency *(a)* and basal area *(b)* distributions of loblolly and shortleaf pine for stands near Pine Bluff, Arkansas (adapted from Olmsted (1902)).

ten published pictures of "trophy" hardwoods and baldcypress, many of which exceeded 120 cm DBH (e.g., Anonymous 1909). Isolated sycamore (*Platanus occidentalis* L.), sweetgum, post oak, and white oak > 100 cm DBH can still be found across the UWGCP.

Growth and Yield. Recovering growth rates for presettlement pines was particularly difficult

Table 2. Maximum loblolly and shortleaf pine dimensions reported for UWGCP virgin forests.

Source	Location	Species	Height (in m)	Diameter (in cm)	Notes[a]
American Forests (2000)	Warren, Arkansas	loblolly	45	152	1
	Myrtle, Mississippi	shortleaf	27	112	1
White (1984)	Urania, Louisiana	loblolly	54	—	2
	Urania, Louisiana	loblolly	56	—	2
Chapman (1913)	Crossett, Arkansas	loblolly/shortleaf	—	>100	3
Chapman (1942)	Urania, Louisiana	loblolly	50	132	4
	Urania, Louisiana	loblolly	—	137	
GLO survey notes	Ashley County, Arkansas	loblolly (?)	—	183	5
	Ashley County, Arkansas	loblolly/shortleaf	—	>100	3
Mohr (1897)	Gurdon, Arkansas	loblolly	—	122	
This study	Hamburg, Arkansas	loblolly	—	142	6
	Hamburg, Arkansas	shortleaf	43	90	7
	Ashley County, Arkansas	shortleaf	—	127	8

[a] Notes on data: 1 = current national champions, 2 = "Sentinel Pines," 3 = did not distinguish loblolly from shortleaf pine, 4 = "Buzzard Pine," 5 = judging from pine's location, this is probably a loblolly, 6 = "Morris Pine" near the Levi Wilcoxon Demonstration Forest, 7 = new state champion shortleaf pine near the Levi Wilcoxon Demonstration Forest, 8 = see Figure 8.

Table 3. Average growth and yield of even-aged stands of pine "under ordinary conditions" in Ashley County, Arkansas (adapted from Chapman (1912, p. 469) and Chapman (1913, p. 8)).

Age of stand (years)	Yield (m^3/ha)[a]	Growth (m^3/ha/yr)
50	29.3	0.59
60	38.5	0.64
70	47.2	0.68
80	55.9	0.71
90	64.2	0.71
100	72.2	0.73
110	79.3	0.73
120	86.4	0.71
130	92.0	0.71
140	96.8	0.68
150	100.3	0.66
160	102.7	0.64
170	102.7	0.61
180	101.5	0.57
190	98.6	0.52
200	94.4	0.47
210	88.7	0.45
220	80.5	0.38
230	71.0	0.31

[a] 1,000 board feet per acre (1 Mbf/ac) = 5.83 m^3 per hectare.

because early observers were interested in yield, not increment. Virgin loblolly and shortleaf pines were several times more likely to produce high annual ring density boards (> 8 rings per 2.54 cm) than those second-growth (Davis 1931). The height and volume growth rates of unmanaged loblolly and shortleaf pine declined at 30 to 50 years of age (Mlodziansky 1896; Mohr 1897), although diameter increment can remain appreciable for several more decades. Loblolly pine generally grew faster than shortleaf pine (Mohr 1897; Olmsted 1902; Record 1910; Mattoon 1915). For example, Mohr (1897) estimated that an "average" loblolly would reach 29.9 m in height and 49.5 cm DBH at 100 yr, while a comparable shortleaf would be 24.7 m tall and 43.2 cm DBH.

Typically, average stand production rates in old-growth pine stands are low. Bond (1939) reported an average annual growth of 1.4 m^3/ha (1 m^3 = 423.7 board feet, 1 ha = 2.47 acres) for an old-growth pine forest in the UWGCP. Chapman (1912; 1913) estimated the annual volume increment of virgin pine forests in southeastern Arkansas (Table 3) peaked at 100 years (0.73 m^3/ha/yr) and declined in productivity to at least age 230 (0.31 m^3/ha/yr). Second-growth natural pine stands under uneven-aged management in this same area on similar sites can grow 1.9 to 3.1 m^3/ha/yr, depending on initial stocking (Williston 1978; Baker and Murphy 1982).

Most aboveground live volume in virgin forests was concentrated in a few large individuals (Fig. 8). Although individual virgin pines typically yielded less than 2.1 m^3, some grew substantially bigger (Morbeck 1915; Mattoon 1926; Chapman 1942; White 1984). Louis L. Morris (for whom the Morris Pine was named) stated that when he first started to work for the Crossett Lumber Company in 1907 ". . . there were virgin trees with as much as 7,500 board feet [17.7 m^3] in them. . . " and ". . . a single log was a heavy load for an ox wagon. . . ." (Anonymous

Fig. 8. Only a handful of large pines could contribute the majority of a stand's volume. This 190 year old shortleaf pine was cut in the Crossett, Arkansas area around 1943. The tree produced a merchantable bole 18.3 m long, 127 cm diameter on the butt log, and 81 cm diameter at the top of the top log (notice the man in the background). The bottom log alone produced 3.2 m^3 (1,350 board feet) of sawtimber. (Picture courtesy of the Crossett City Library.)

Table 4. Sawtimber yields reported for virgin pine forests in the Upper West Gulf Coastal Plain. Few authors reported the log scaling rule they used, so yields were converted as provided (1000 board feet per acre (1 Mbf/ac) = 5.83 m^3 per hectare).

Source	Location	Yield (m^3/ha), range [average]	Commentary
Anonymous (1890)	Ashley County, Arkansas	na[a] [46.7]	average over 855 km^2 "pine cordon" area
Mohr (1897)	south Arkansas	34.9–46.7 [na]	50% shortleaf, 50% loblolly
Olmsted (1902)	Pine Bluff, Arkansas	na [34.7]	pine ridge type, 64% shortleaf, 36% loblolly
	Pine Bluff, Arkansas	na [38.7]	pine flat type, 68% loblolly, 32% shortleaf
Record (1907)	Arkansas	29.3–87.6 [40.8]	pine-dominated rolling lowlands
Chapman (1912)	Ashley County, Arkansas	71.0–102.7 [na]	"ordinary" pine stands
Chapman (1913)	Ashley County, Arkansas	na [47.4]	50% shortleaf, 50% loblolly
Morbeck (1915)	south-central Arkansas	40.8–58.3 [na]	80% pine, 20% hardwoods
Garver and Miller (1933)	east Texas flatwoods	na [61.8]	92.5% shortleaf, 7.5% loblolly
Cruikshank (1938)	northwest Louisiana	na [74.0]	pure pine type
	northwest Louisiana	na [51.9]	shortleaf-loblolly-hardwoods
Maxwell and Martin (1970)	eastern Texas	30.0–37.0 [na]	
Reynolds (1980)	Crossett, Arkansas	up to 146 [41.0]	

[a] na = not available (no value was presented in the original citation).

1950, p. 3–4). A photograph taken in 1910 in Bradley County, Arkansas shows a man standing next to a felled pine with the number "7226" scrawled on the cut face (Eagle Democrat 1991). Presumably, as was the custom of this era, this number represented the board foot tally of the tree (equal to 17.1 m^3). Record (1910) reported a single loblolly pine cut in Pike County, Arkansas that yielded seven 3.7 m long logs scaling 4.08, 3.43, 3.12, 2.83, 2.69, 2.29, and 2.19 m^3 (a grand total of 20.63 m^3). The largest pine cut from the Fordyce Lumber Company's lands in south-central Arkansas tallied 21.0 m^3 (Morbeck 1915) and Chapman (1942) described a loblolly pine near Urania, Louisiana that scaled 25.5 m^3 (both are greater than some stand averages).

The impressive size of some pines did not usually translate into high stand yields, as many large-scale estimates of pine volume were surprising low (Table 4). For example, Harvey (1883) estimated the 51,800 km^2 of pine lands in Arkansas (including areas outside of the UWGCP) averaged 18.2 to 22.9 m^3/ha in trees greater than 38 cm in diameter. Harvey's estimate predates most of the land clearing associated with logging and agricultural operations, so low yields arose largely from the openness of virgin pine stands. Spatial heterogeneity of stocking also produced noticeable yield variation. Westveld (1935) provided a figure of 58 m^3/ha for a "typical" virgin loblolly/shortleaf pine stand, with some locations approaching 175 m^3/ha.

Table 4 summarizes other stand-level yield reports for the UWGCP. Most of these estimates place average volume yields of presettlement old-growth pine forests in this region at 30 to 70 m^3/ha. Even though none of the authors noted more than 150 m^3/ha in the pine component as suggested by Westveld (1935), some limited areas likely approached this volume. Few observers reported non-pine yields from virgin pine forests of the UWGCP, but only scattered merchantable hardwoods were probably encountered. Of the pine-dominated forests of south-central Arkansas, Morbeck (1915) placed the hardwood contribution to average merchantable yield at 20%, primarily from white oak. Morbeck's non-pine fraction is similar to those provided by Baker and Bishop (1986), who estimated the yield of the proposed Reynolds RNA to include 47.7 m^3/ha of pine and 13.0 m^3/ha in hardwoods.

Age Structure. Advanced age is an important attribute of old-growth. Gaines et al. (1997) set the minimum age for old-growth consideration (beginning at 100 to 140 years) at one-half the species longevity. Recent surveys of old-growth loblolly pine stands in the southeastern United States have found numerous individuals up to 200 years old (Jones 1971; Stalter 1971; Pederson et al. 1997). White (1984) believed that loblolly pine could reach 400 years old, although a peak age of 150 years was more common. Mattoon (1915) reported a similar maximum age (400 years) for shortleaf pine, and called trees in the 200 to 300 year range "common." Chapman (1913, p. 6) stated that the pine (both loblolly and shortleaf) he inventoried south of Crossett ". . . rarely exceeded 150 years, although occasional very old trees may reach 200 years." The Morris Pine was estimated to be 250 years old in 1950 (Anonymous 1950), and this would place its age at ~ 300 years today. The proposed R.R. Reynolds Research Natural Area on the Crossett Experimental Forest has no pines older than 150 years (Shelton and Cain 1999), but this is a limitation imposed by high-grading during the original harvest circa 1915.

Forbes and Stuart (1930) believed that most presettlement pine forests in the South were uneven-aged. The irregular diameter distribution in many of the virgin pine stands reported in this study suggest that multiple age classes were indeed present. However, the frequency of fire, windthrow, and other large-scale catastrophic disturbances would have ensured that large areas of the UWGCP were occupied by even-aged forests. As an example, Turner (1935) attributed three virgin even-aged shortleaf pine stands in southwestern Arkansas to tornadoes.

Tree Form. Individual tree form is an important yet intangible property of old-growth. Tree character develops from environmental conditions, genetics, and age, and contributes substantially to the impression of old-growth. The lack of lower branches, dead tops, hollow stems, fire scars, smooth bark, reduced bole taper, distorted crown shapes, and low crown vigor has often been associated with old trees (e.g., Jones 1900; Morbeck 1915; Bruner 1930; Chapman 1942; Jones 1971; Stahle and Chaney 1994), and may be as noticeable as any old-growth attribute. For instance, Figure 3 clearly shows the flattened tops and clear boles of the shortleaf pine canopy in a virgin stand near Hamburg, Arkansas.

The openness of many presettlement stands produced robust, spreading crowns supported by many large branches and stout boles, legacies that can still be found (Shelton and Murphy 1990; Marks and Gardescu 2001). Bole taper in canopy dominants was often very slight, producing almost columnar stems in the biggest pines. Chapman (1942) reported a loblolly pine near Urania, Louisiana that was 137 cm at DBH and 102 cm in diameter at a height of almost 30 m above the stump. Shelton and Murphy (1990, p. 621) described old shortleaf pines in the Ouachita Mountains of Arkansas as ". . . apparent from their slick bark, flat or decurved branch angles, and flat upper crowns."

Loblolly and shortleaf pines growing in old-growth stands in southeastern Alabama and northern Georgia had substantially clearer wood (Table 5) than second-growth stands in those same regions (Spillers 1939a,b). A study of lumber grade recovery from sawlogs (Davis 1931) taken from old-growth pine stands in Arkansas, Louisiana, and Mississippi and second-growth pine from Georgia and South Carolina found a higher proportion of quality lumber in the old-growth, even though boards from these stands were more likely to have natural defects like decay, worm holes, shake, and pitch streaks (Table 5).

Spatial Pattern. Well-stocked, managed pine forests tend to have their stems evenly distributed, while relatively undisturbed old-growth forests are more inconsistent in their spatial structure (Smith 1986; Turchin et al. 1999). Unfortunately, descriptions of the spatial pattern of presettlement pine forests are decidedly less quantitative than diameter or age distributions. Hepting and Chapman (1938, p. 1194) noted one of the old-growth shortleaf pine stands they sampled in Texas as ". . . consisting chiefly of large, old shortleaf pines, with a few small pines and a scattering of small, poor quality hardwoods." Historical photographs from the late 19th and early 20th century of the UWGCP (e.g., Fig. 9) often showed open pine forests dominated by large shortleaf and loblolly pine, with few other species apparent (Anonymous 1905; 1906; Buckner 1979; Reynolds 1980; White 1984). Frequent fires are usually attributed as the reason for the open stands and sparse understories (e.g., Olmsted 1902), although unfavorable site conditions also contributed to the presence of scattered prairies and woodlands in Ashley and Drew Counties (Wackerman 1929). Mattoon (1915, p. 34) mentioned that older stands of shortleaf pine are ". . . irregular in density, with many small openings. . . ." Chapman (1913, p. 6) described much of his study area south of Crossett as

> . . . approximately even-aged, but seldom continuous over very large areas. It is more likely to be broken up into different age

Table 5. Bole quality (percent of volume) of sawtimber-sized shortleaf and loblolly pines in old-growth versus second-growth stands by various grading methods.

Source and location	Stand type	Loblolly pine			Shortleaf pine		
		Smooth[a]	Limby[b]	Rough[c]	Smooth	Limby	Rough
Spillers (1939a,b)							
southeast Alabama	old-growth	94	6	0	98	2	0
	second-growth	31	51	18	49	40	11
northern Georgia	old-growth	84	16	0	93	7	0
	second-growth	50	45	5	57	41	2

Source and location	Stand type	B and better	No. 1 Common and C	No. 2 Common	No. 3 Common
Davis (1931)[d]					
Arkansas, Louisiana, and Mississippi	old-growth	15	26	44	15
Georgia and South Carolina	second-growth	3	19	60	18

[a] Trees with ≥ 6.1 m of clear bole and at least 50% of their usable length virtually free of limbs and indications of knots.
[b] Trees with at least 3.7 m of clear bole and 30 to 49% of their usable length free of limbs and indications of knots.
[c] Trees with less than 3.7 m of clear bole, or less than 30% of their usable length free of limbs and indications of knots.
[d] Graded using American Lumber Standards from ~ 1930, with superior boards receiving a B grade or higher, and the lowest quality boards receiving a grade of Number 3 Common.

> classes, clumps of large, overmature trees being interspersed among groups of young timber, small poles, or seedlings.

Similar accounts of patchy forested landscapes in the UWGCP has been provided by others. Olmsted (1902, p. 19) described the pines in his ridge type as "... occur[ing] either in very small groups or scattered about by single trees; more commonly the latter." He found the hardwoods to "... occur [as] single trees, quite evenly distributed." Pine seedlings were "... exceedingly scarce in this type of forest...," probably due to frequent fire. Presettlement southern pine forests are often thought of as multi-aged, although this age structure probably occurred on a greater scale than uneven-aged stands dominated by more shade tolerant species. When developing a means to estimate yield for inconsistent uneven-aged stands, Chapman (1912) introduced a process that mapped "veterans," "mature," and "young merchantable" classes identified by trained crews. The Ashley County stand maps redrawn in Figure 10 represent the same 8 ha stand from the perspective of three different crews. Though discrepancies in crew interpretation make detailed comparison of the results difficult, the patchy nature of these stands is apparent. Most of the area was covered with by small- to moderate-sized trees, with the veterans occurring as scattered clusters or individuals. Because of the closer correlation between tree size and age, a multi-tiered size structure in stands dominated by shade intolerant species suggests an uneven-aged forest.

Understory and Forest Floor Conditions. Very little information on the understory and forest floor of the virgin forests exists. Stands comparatively free of undergrowth were commonly described for presettlement pine forests in the southeastern United States. Reed (1905, p. 13) remarked that forests in central Alabama had "... ground cover consist[ing] of a thin and straggling growth of grass and other herbaceous plants... particularly on steep rocky slopes or on the tops of the high ridges...," however, overgrazing may have contributed to this condition. Maxwell and Martin (1970, p. 2) reported the original east Texas pinery as

> ... great pine stands... largely free of undergrowth and travelers remarked on the park-like appearance of the forest floor. One observer pictured the forest as "in its virgin state there was little or no undergrowth save along the watercourses, but the

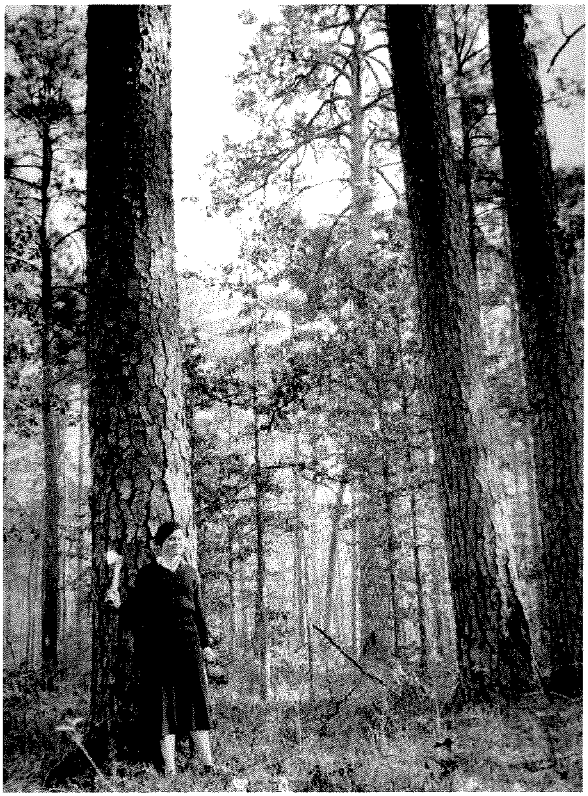

Fig. 9. The openness of upland pine stands in the Upper West Gulf Coastal Plain is frequently observed in historical photographs. This picture, taken in 1934 near Crossett, Arkansas, clearly shows the scattered large pine intermixed with small hardwoods. Note the large burn scars on the pine and open understory, suggesting the role of fire in presettlement forests. (Picture from the U.S. Department of Agriculture, Forest Service's Crossett Experimental Forest archives.)

trees rose in stately grandeur from a luxuriant carpet of the finest green."

It was not unusual for the General Land Office (GLO) surveyors to report undergrowth as ranging from dense to virtually absent (Delcourt 1976; Foti and Glenn 1991). Briars and cane (*Arundinaria gigantea* (Walt.) Muhl.) were often mentioned in the GLO surveys of southern Arkansas, as was the occasional pine or hardwood sprout. Record (1907, p. 298) found the loblolly pine flatlands of Arkansas dominated by ". . . ground cover var[ying] from weeds and grass to dense thickets of wax-myrtle [(*Myrica cerifera* L.)], brambles, sumac [(*Rhus* spp.)], and hardwood sprouts. . . " and the shortleaf pine-dominated ridges were usually occupied by wax myrtle and huckleberry (*Vaccinium* spp.). Olmsted (1902, p. 19) described the undergrowth of pine ridge areas near Pine Bluff, Arkansas as ". . . found both in large and small groups and scattered openly and irregularly, while over large areas it is entirely absent, leaving the ground clear and bare under mature trees."

Morbeck (1915) also reported open understories in upland pine stands near Fordyce, Arkansas, with good oak and pine regeneration in many places (see Figs. 2 and 9). Pine regeneration in places was so successful that Mohr (1897, p. 108) repeated a quaint proverb that in upland southern forests of the late 19th century, ". . . the pine is crowding out the hard-wood timber. . . ." Pine establishment is also aided by the exposure of mineral soil and the limited accumulation of litter. Olmsted (1902, p. 18) had described the humus as

> . . . almost entirely absent, and the ground cover consists of a thin and scattered layer of needles and leaves, together with grass, weeds, and ferns. On the most open places and irregular patches throughout the forest are more or less dense growths of Huckleberry, Laurel, Swamp Bay, and briers.

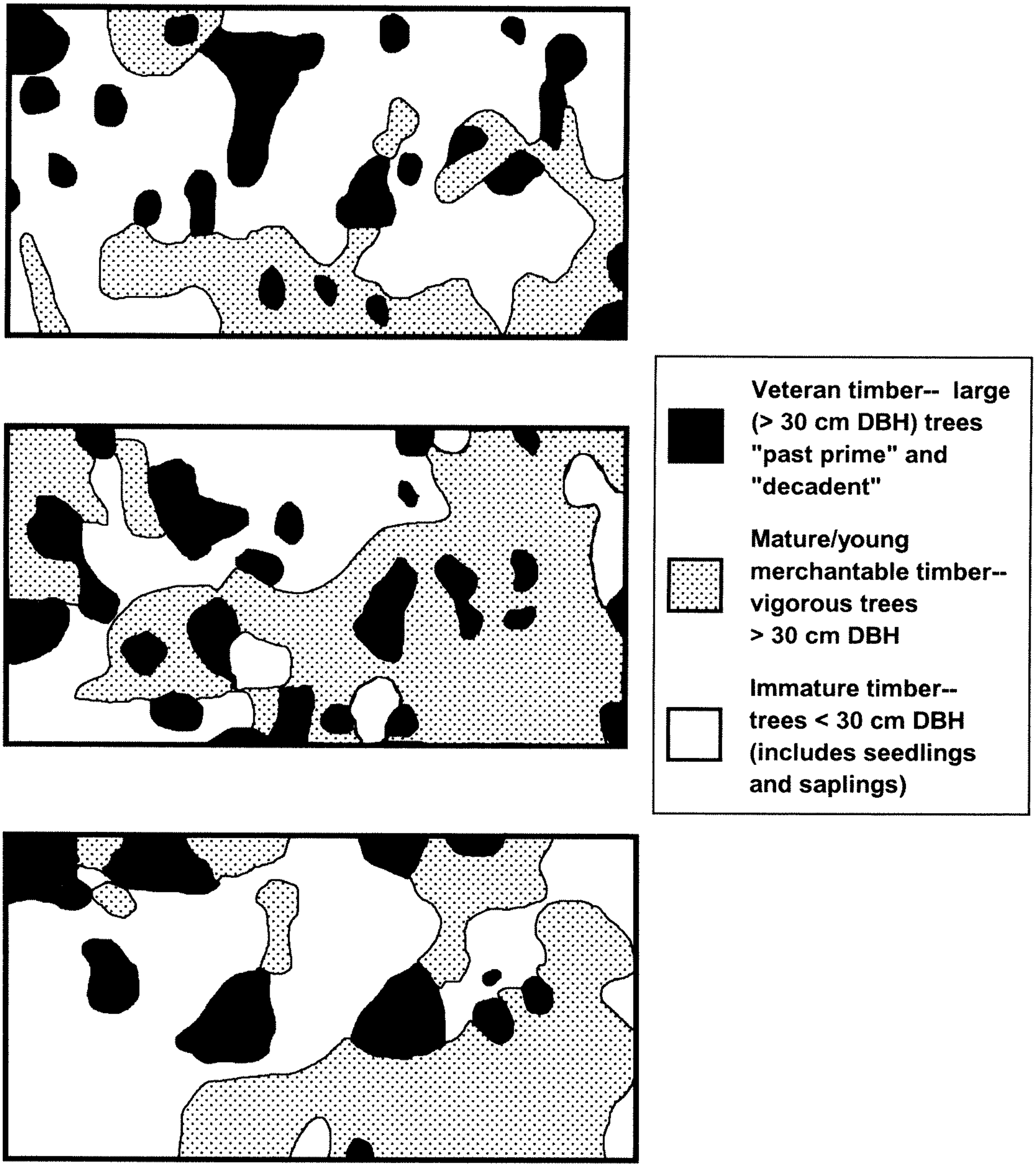

Fig. 10. Approximations of stand structure developed by one of H.H. Chapman's field classes for 8.1 ha of virgin pine south of Crossett, Arkansas (adapted from Chapman (1912)). Each map is a different group's interpretation of structure for the same stand. While the subjectivity inherent to using multiple groups to create these maps is undeniable, it provides a rare glimpse of the spatial pattern of loblolly/shortleaf pine stands early in the 20th century. Note the patchy distribution of "veteran" timber in a matrix of mature, young merchantable, and immature areas.

Olmsted (1902) attributed the lack of surface organic matter to frequent fires. As for the pine flats, Olmsted (p. 22) noted the following:

> Over considerable areas on these flats, and especially in the open spaces, there is a dense and often quite high growth of grass, and the usual ground cover of leaves, weeds, ferns, and huckleberries is common throughout. As on the [pine] ridges, the humus layer is exceedingly thin or entirely absent.

Vines of grape (*Vitis* spp.), rattan (*Berchemia* *scandens* (Hill) K. Koch), honeysuckle, poison ivy (*Toxicodendron radicans* (L.) Kuntze), and greenbrier were frequently encountered by the GLO surveyors, although these species are rarely seen in historical photographs of UWGCP pine stands (Fig. 9 and Anonymous (1904a,b; 1905; 1909)). Since climbing vines are very common in modern forests, their absence in historical photographs suggests that their abundance (or at least their vertical distribution) has changed notably in recent decades. This may prove an artifact of an altered fire disturbance regime, as exposed, thin-barked vines are easily killed and even severed by light surface fires. Disturbance from agricultural and silvicultural practices may have also significantly improved establishment conditions for many vine species, thus contributing to their increased success.

Not surprisingly, the undergrowth for current examples of old-growth in the UWGCP appears quite different from presettlement stands. Chapman (1942) cited the successful exclusion of fire as primarily responsible for the accumulation of pine-inhibiting litter and proliferation of hardwood and brush thickets. Dense overstories, whether pine or hardwood, effectively eliminate the high-light conditions needed to ensure good pine reproduction (Jackson and Harper 1955; Stalter 1971). These patterns are similar to those noted for other old-growth southeastern pine stands (Lipps and de Selm 1969). The understory of the proposed Reynolds RNA is dominated by woody shrubs and hardwood seedlings and saplings, with sparse cover of graminoids and forbs (Cain and Shelton 1994). Poison ivy, grape, honeysuckle, rattan, and greenbrier vines can be found extending into the mid- and overstory tree canopies of both the Reynolds RNA and the nearby Levi Wilcoxon Demonstration Forest, as well as many other mature forests of the region.

Historical Disturbance Patterns. Reconstruction of presettlement disturbance patterns for the UWGCP is a necessary part of any restoration effort intended to be self-maintaining because the observable features of these historic landscapes arose, in part, from the events that perturbed them. Old-growth is a product of a dynamic environment that helps to both organize and disassemble communities and landscapes, and when decoupled from this system, primary forests deviated from presettlement patterns. Understanding the range of variation and uniqueness of virgin forests affected by perturbation should allow for improved restoration efforts, because it is virtually impossible to maintain an exact, unchanging ecosystem to meet statutory or regulatory interests (Noss 1985).

Changes from presettlement natural disturbance regimes are often some of the most noticeable differences in old-growth stands, past to present (Chapman 1947; Dickson 1991). Our understanding of the patterns and processes of presettlement disturbance is sketchy, and speculation on the dynamics of these events dominates our knowledge. Unique presettlement vegetative states arose from differences in disturbance type, intensity, or periodicity (e.g., Frelich and Lorimer 1991; Shinneman and Baker 1997), and even the same type of disturbance (e.g., wind or fire) could yield significantly different outcomes, especially when impacting stands of different ages. Disturbances are also inconsistent in their degree of "harmfulness." Even though perturbations killed or injured at least some of the standing timber, this damage is beneficial to other organisms. For example, ice and wind storms often breaks branches from the crowns of the dominant pines. These wounded trees are vulnerable to heartrot, which in turn produces a decay column in the still-living pine that can be colonized as nesting habitat.

Fire. The sparsely stocked pine-dominated forests of the southern United States have been thought the product of frequent burning, whether natural or human caused (e.g., Olmsted 1902; Reed 1905; Chapman 1942; 1947; Dickson 1991; Key 2000). Naturally- and anthropogenically-ignited fires anually affected a large portion of the presettlement UWGCP (Hamel and Buckner 1998; Carroll et al. 2002), although it is virtually impossible to reliably quantify the extent burned. Not surprisingly, the reckless and indiscriminate use of fire and vulnerability of cutover lands spurred many calls for fire suppression, especially when only negative commercial effects like the limitation of forest productivity and the destruction of commodities were considered (Olmsted 1902; Reed 1905; Rothkugel 1907; Record 1907; Bruner 1930). However, even with the fire-related problems of the UWGCP, some early observers recognized fire's usefulness to control hardwood and brush competition (Rothkugel 1907; Chapman 1942; Bruce 1947; Harrington and Stephenson 1955).

Shortleaf and loblolly pine, though not as fire-tolerant as longleaf pine, can often withstand repeated burning because both species become resistant to fire at an early age (Olmsted 1902; McNab 1977). Young shortleaf also have a substantial capacity to resprout from rootstock if the fire has not been too intense (Olmsted 1902; Mattoon 1915). Fire scar frequency increases with tree size (and, presumably, age): both Bruner (1930) and Forbes and Stuart (1930) reported research that found up to 30 to 50% of large (> 46 cm) stems had visible fire scars. Garver and Miller (1933) and Hepting and Chapman (1938) found that 9 to 13% of the pines in some old-growth shortleaf stands in Texas had fire wounds, while less than 2% of second-growth pines in southern Arkansas showed such damage. However, injuries from fire were common in second-growth pine stands when exclusion was ineffective (Garren 1941). Davis (1931) attributed the relatively high occurrence of pitch and pitch streaks in old-growth pine of Arkansas, Louisiana, and Mississippi to their frequent exposure to fire.

In part, fires were considered limiting to productivity because they destroyed advanced regeneration (Olmsted 1902; Reed 1905; Chapman 1913; Forbes and Stuart 1930; McNab 1977). Bruner (1930, p. 23) noted that "typical" old-growth pine forests of east-central Arkansas were ". . . growing trees at only 53 per cent of their capacity. . . ," and that ". . . one-fourth of the area was producing only at 30 per cent. . . ." Many hardwoods have a greater sprouting capacity than the pines, but repeated severe fires often resulted in stunted and decayed survivors and, possibly, death (Morbeck 1915; Bruner 1930; Westveld 1935; Harrington and Stephenson 1955).

Fire damage often interacted with other types of disturbance. Chapman (1942) mentioned that repeated fires weakened standing trees and made them more susceptible to toppling. Olmsted (1902) recounted the early shingle making practice of cutting into standing live trees to check for their quality. Individuals that did not meet standards were left, and highly flammable pitch seeped out of the injuries. The pitch could then harden into masses and become a pathway for a fire to burn into the trunk of the tree, making them more susceptible to windthrow. Olmsted (1902, p. 9) reported that "[a] large part of the 'down' timber on the tract has been thrown in this way. . . ," although he did not quantify this statement further.

Windthrow. Windthrow was a major cause of mortality in the presettlement pine forests of the UWGCP. Early surveyors commonly reported wind damage in their notes, with scores of areas identified in southeastern Arkansas alone. Shallow rooting depths and high soil moisture contributed to windthrow (Chapman 1913), although Westveld (1935) and Fredericksen et al. (1993) downplayed the risk to loblolly and shortleaf pine because of their strong taproots. However, the UWGCP is susceptible to severe wind disturbances (primarily tornadoes, frontal systems, and hurricanes) that can produce considerable damage regardless of rooting habit.

Zon (1905) described extensive windthrow (probably hurricane-related) in 1865, 1873, and 1900 for loblolly pine-dominated stands in eastern Texas. Tornadoes were occasional visitors to the UWGCP (Cole 1927). Interviews with longtime Crossett, Arkansas residents suggested tornadoes struck the area in 1875, 1893, 1915, 1919, and 1938, resulting in the loss of millions of board feet of standing timber (Ashley County Genealogical Society 1995). Turner (1935) remarked that the young, almost pure stands of pine that arose in blowdown areas (dubbed "hurricane forests", although most were caused by tornadoes) may reflect a primary mechanism in which even-aged stands of pine were formed.

Ice Storms. Severe ice storms have produced widespread damage to UWGCP pine forests (e.g., Mattoon 1915; McKellar 1942; Muntz 1947; Watts 1951). For instance, a single ice storm in Texas and Louisiana covered at least 3.2 million hectares and inflicted severe damage over one-quarter of this area (White 1944). The UWGCP usually experiences between one and four damaging ice storms per decade (Bennett 1959; Cool et al. 1970; Guo 1999). Most events are relatively minor, rarely exceeding 1 cm of ice accumulation, but some ice storms have produced more than 5 cm of glaze (Bennett 1959). Mattoon (1915, p. 39) reported a glazing event in southwestern Arkansas in December of 1898 that ". . . broke down so many trees that it completely blocked road traffic over all of the timbered roads for nearly one week. . . ."

Glaze storms are particularly injurious to exposed, spindly, decayed, or asymmetrical trees (McKellar 1942; Nelson 1951; Shepard 1978). Open-grown trees are thought to be less vulnerable to ice damage than those found in closed stands, although dense stands may prove resistant if the spacing is such that individuals trees can support each other (Cool et al. 1971; Schultz 1997). Recently exposed young pines often experience the heaviest damage (Brender and Romancier 1960; Burton and Gwinner 1960; Shepard 1978), although severe ice storms can even damage or kill large trees. Lipps and de Selm (1969) reported the loss of approximately one-quarter of the big pines in the Marshall Forest of Georgia from the 1960 ice storm.

In the open virgin pine forests of the UWGCP, glaze storms probably helped thin the smallest size classes while having little impact on the largest trees. Ice storms may also prove ecologically important over large spatiotemporal scales, for they can shift the composition of stands via differential response of species to ice loading. For example, Burton and Gwinner (1960) reported more damage in young loblolly pine than comparable shortleaf pine after an ice storm struck the southern Appalachians and Cumberland Plateau. The longer needles, thicker foliage, and more rapid growth of loblolly pine may cause it to be more susceptible to breakage or uprooting, thus putting it at a disadvantage to shortleaf pine.

Drought, Flood, and Lightning. The occurrence of droughts, floods, and lightning are independent of the developmental stage of the forest, but the impacts of these disturbances on the ecosystem are not. Vegetative cover and age, relative tolerance of extreme moisture conditions by species, and tree size and robustness all interact to influence the response of forests to these perturbations. Additionally, these factors can contribute to the severity and extent of other disturbances like fire, insect outbreaks, and disease by weakening live trees and providing favorable habitats.

The UWGCP is periodically affected by extremes in moisture (Chapman 1942; Stahle et al. 1985), whether they manifest themselves as severe droughts or flooding. Excessively low soil moisture can limit forest productivity, especially for a region where growing season demands for moisture are substantially higher than precipitation inputs (Reynolds 1958). Hardwood understories significantly increased the depletion of soil water by pine forests in southern Arkansas (Zahner 1958), and well-stocked stands proved more consumptive than thinned ones (Moyle and Zahner 1954). Thus, it may be inferred that virgin pine forests, with their lower stocking and sparse hardwoods, may have been less susceptible to drought. Floods are uncommon across most of UWGCP except in the bottomlands. Excessive water is more likely to affect loblolly pine because this species is more abundant in low or wet areas than shortleaf pine.

Lightning kills a considerable number of pines every year in the UWGCP (Baker and Langdon 1990). Reynolds (1940) attributed 70% of the volume lost to natural causes over a two-year period on the Crossett Experimental Forest directly or indirectly (via post-strike insect mortality to struck and adjacent trees) to lightning. Since isolated big trees have a higher probability of being struck, lightning mortality could be extensive in mature timber during a particularly severe storm (Reynolds 1940). Therefore, one may expect that old-growth forests would suffer disproportionately higher losses than younger, even-aged stands. Lightning is also responsible for many of the fires in Arkansas, both past and present (Bruner 1930).

Insects and Other Animals. Even though some early writers dismissed insect damage as minor (Reed 1905), others felt it was one of the most important causes of timber loss (Chapman 1913). Curry (1953) described insect problems prior to 1940 as insignificant, but that a sawfly (probably *Neodiprion taedae linearis* Ross) outbreak beginning in 1940–1941 in southern Arkansas was of great concern. Chapman (1913) felt that up to 5% of mature pines in southern Ashley County were killed over a few growing seasons by insect outbreaks (especially bark beetles (*Dendroctonus* spp.)). Indeed, bark beetle infestation has caused widespread mortality to the pine overstory on the proposed Reynolds RNA (Cain and Shelton 1996) and the Murder Creek RNA in central Georgia (Harrington et al. 2000).

Insect outbreaks are often confounded with the occurrence of other types of disturbance. Logging, severe weather, or fire can wound standing timber, thus providing an attractant for insects, especially bark beetles (Reynolds 1940; Garren 1941; Cool et al. 1971; Ku et al. 1980). For instance, Jones (1900) decried the loss of residual pine timber to insects and disease following summer harvesting in Texas. However, the thinning of mature loblolly pine stands appears to help minimize the spread of southern pine beetle (*Dendroctonus frontalis* Zimm.) (Turchin et al. 1999). The lower density of virgin pine forests probably helped limit the severity of beetle outbreaks, although much of the unique spatial pattern of presettlement old-growth (open stands interspersed with solitary dominants or small patches of large trees) resulted from earlier beetle kills. Insect damage patterns have also changed due to the loss of old-growth habitat of woodpeckers, one of their most important natural predators.

Native and introduced mammals can also cause tree mortality, although rarely are they damaging to large trees. While presettlement estimates of deer densities are uncertain (Schoen et al. 1981), white-tailed deer (*Odocoileus virginianus* Zimm.) herds in eastern North America have grown rapidly in recent decades. Leopold et al. (1947) mapped much of the UWGCP as having few to no deer, although this probably reflects an incomplete recovery of deer populations following their near extinction earlier in the century. White-tailed deer (as well as any other overabundant herbivore) can alter forest succession through lethal browsing of seedlings and saplings. Mortality to young trees can also arise from the polishing of deer antlers on tree trunks, but this is not a major problem in most areas. Other large native ungulates like bison (*Bison bison* L.) and elk (*Cervus elaphus* L.) were probably of little consequence in the pine forests of the UWGCP before they were extirpated.

Introduced livestock, however, did pose a serious threat to forests, at least by the early 20th century. Feral hogs cause localized problems by consuming the mast of many species, damaging understory vegetation, and uprooting pine seedlings (Maxwell and Martin 1970; Wood and Lynn 1977). Interestingly, Olmsted (1902) defied conventional forestry wisdom by promoting hog ranging on land near Pine Bluff, Arkansas because the hogs consumed mostly acorns and apparently did little damage to the preferred pine seedlings, while their foraging improved the seedbed. Much of the landscape was converted to pasture following the removal of the virgin forest, with some lumber companies importing exotic breeds of cattle in an unsuccessful attempt to encourage pastoralism (and, theoretically, increase the value of their cutover property) (Mety 1952; Reynolds 1980). Fire was commonly used to suppress the pines, hardwoods, vines, and briars that could rapidly recolonize pastures, but when carelessly applied, these fires damaged uncut timber (Rothkugel 1907; Strausberg and Hough 1997). Hunters also frequently set fire to southern forests to improve conditions for game, often with little regard to the consequences to timber and farms (Foster 1912; Key 2000).

The changes wrought by settlement, land development, and game management have undoubtably influenced animal communities (Schoen et al. 1981; Dickson 1991; Hamel and Buckner 1998) and thus altered the potential to completely restore historical forest conditions. The red-cockaded woodpecker, for instance, seeks out mature live pines infected with red heart in open woodlands. Large pines infected with red heart are common in old-growth (e.g., Nelson 1931; Jones 1971) and the virgin forests often had sparse, forb- and grass-dominated understories characteristic of frequently burned ecosystems (Bukenhofer et al. 1994; Carroll et al. 2002). The elimination of this habitat across much of the southern United States has pushed the red-cockaded woodpecker to the brink of extinction (Steirly 1952; James and Burnside 1979; Lennartz 1988). The systematic management of forests primarily for game species has also undoubtedly affected the dynamics of the system (Wood and Lynn 1977; Key 2000), especially by favoring mast species and early successional cover types.

Heart Rot and Other Tree Decay. The decay of live trees is an attribute that often manifests itself most notably in old-growth stands. Healthy trees are usually vigorous enough to repel most invasions, but with time and the accumulation of damage, pathways for infection become more prominent. Young shortleaf and loblolly pine are usually resistant to the principal heart rot of the region, "red heart" or "red rot" (primarily from the fungus *Phellinus pini* Ames). Slow growth and a high proportion of heartwood are important factors in the development of heart rot in many southern pines (Lightle and Starr 1957), which typically enters through branch stubs or fire scars (Hepting and Chapman 1938; Garren 1941). Affeltranger (1971) reported the following factors played an important role in red heart presence: stand age (especially for uneven-aged stands); large, persistent branches; increasing proportion of pine; and excessively drained, shallow, or soils with high nitrogen content.

It is not unusual to spot red heart cankers on old pines in historical photographs (e.g., Anonymous 1904b; 1906; Chapman 1913). Both Zon (1905, for loblolly pine) and Mattoon (1915, for shortleaf pine) described heart rot as rare in trees less than a century old, but increasing beyond this age. This trend is supported by numerous other authors (Table 6), who noted increasing cull proportions from decay in older stands. For example, a mill lumber recovery sample com-

Table 6. Percent of stems affected by heartrot and other cull for loblolly and shortleaf pine-dominated stands.

Source	Location	Stand age (years)	Percent cull	Commentary
Zon (1905)	eastern Texas	70–80	<1	red heart in loblolly
Chapman (1913)	Crossett, Arkansas	"old"	3–10	red heart and butt rot
Matoon (1915)	central Arkansas	60–65	2	heartrot in shortleaf
	central Arkansas	170	17	diseased shortleaf
	Arkansas	"virgin"	11–14	unsound logs at sawmills
Nelson (1931)	Virginia	40–90	5	red heart in loblolly
	Virginia	90–140	19	red heart in loblolly
	Virginia	140–190	60	red heart in loblolly
	Virginia	190–230	72	red heart in loblolly
Hepting and Chapman (1938)	Arkansas	"2nd growth"	4	loblolly and shortleaf
	Texas	"old-growth"	7	shortleaf
Lightle and Starr (1957)	Mississippi	65	21	slow growing loblolly and shortleaf
Gruschow and Trousdell (1958)	North Carolina	90	6	old-field loblolly
	North Carolina	"virgin"	14	

posed of a mixture of shortleaf and loblolly pine from virgin stands in Arkansas, Louisiana, and Mississippi had many times greater occurrence of shake, worm holes, decay, pitch, and pitch streaks than one taken from second-growth stands in Georgia and South Carolina (Davis 1931).

Large Woody Debris (LWD). The accumulation of LWD has been recognized as an important indicator of old-growth conditions (Martin 1991; Devall and Ramp 1992; Spetich et al. 1999), but the humid climate and abundant detritivore and decompositional communities of the UWGCP contribute to rapid LWD loss (see Cain 1996). LWD longevity depends on species, wood density, the manner of tree death, the local microclimate, and other losses due to salvaging, fire, or detritivores (Mohr 1897; Long 1917; Harmon et al. 1986; Van Lear 1996; Spetich et al. 1999). Decay resistant heartwood makes up a larger fraction of bole volume with increasing age, with old pines often possessing twice the proportion of heartwood as younger stems (Davis 1931; Demmon 1936). While pitch-saturated heartwood in old, slow-growing trees resists biotic decomposition, this "rich pine" is highly flammable and therefore more susceptible to fire.

Reconstruction of presettlement LWD loads is difficult because of the lack of historical reports. Ligon (1971) believed the occurrence of standing dead timber in southern forests was uncommon in presettlement times because of its consumption by fire (see also Westveld 1935). Even though he did not speculate on the cause of the mortality, Zon (1905) noted the presence of dead loblolly pine in his Texas pine stands (comprising from 2 to 13% of all stems). Studies of contemporary old-growth have found LWD volumes in the range of 30 to > 400 m^3/ha in eastern forests (e.g., Harmon et al. 1986; McMinn and Hardt 1996; Greenberg et al. 1997; Spetich et al. 1999; Zhang 2000). Cain and Shelton (1996) encountered 8 to 56 snags per hectare in the Reynolds RNA, primarily large pines killed by bark beetles. Decadent (i.e., hollow, spike-topped, or otherwise damaged) live trees tend to be more common in unmanaged old-growth (Davis 1931; Greenberg et al. 1997).

Human Influences. The long history of human settlement in the southeastern United States complicates the understanding of presettlement forest conditions. Changes in agricultural and settlement practices, population density, and commercial interests resulted in a patchwork of successional stages and stand structures. Native Americans cleared land for agriculture, then abandoned their fields when the productivity dropped, the farmers died, or the tribes were forced off of their lands. Early Euroamerican settlers often followed similar patterns of land use: White and Lloyd (1995) described a stand of "old-growth" in South Carolina (the 200 year old John de la Howe Tract) that arose following development in the mid-1700s.

Native Americans occupied the UWGCP for millennia before Euroamerican development began in the seventeenth and eighteenth centuries. Even though Native American population estimates are uncertain for the UWGCP at the time of the first contact with Europeans, they probably ran into the many thousands until disease and strife reduced them to perhaps 5 to 10% of

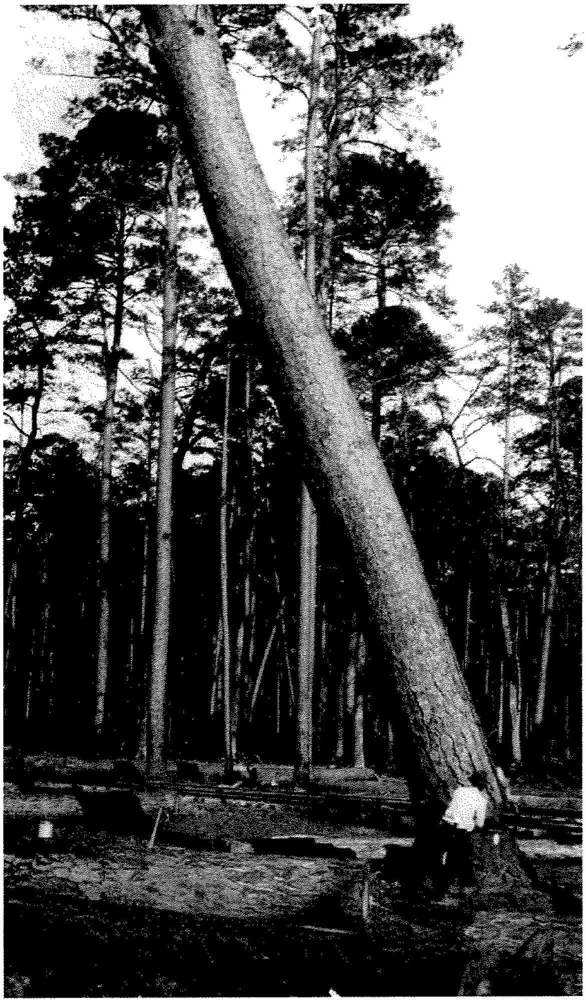

Fig. 11. Intensive logging begun during the late 19th and early 20th centuries continues to the present day, although very few pines this size remain in the Upper West Gulf Coastal Plain. (Photo courtesy of the Crossett City Library.)

their historical levels (Schambach and Newell 1990; Carroll et al. 2002). After this reduction, the landscapes of the UWGCP were sparsely populated for many decades until the beginning of the 20th century, during which they were primarily used for subsistence agriculture, grazing, hunting, and trapping. Conflicts over the use of the land after Euroamerican exploration hastened the anthropogenic perturbation of the UWGCP (Key 2000) and the removal of Native Americans and subsequent development brought this region starkly different disturbance regimes.

Small-scale timber removals began in the 1830s and 1840s in southern Arkansas (Etheridge 1959), but due to the primitive sawing techniques, lack of local markets and labor, the Civil War and Reconstruction, and difficulty in transporting materials, extensive exploitation waited until late in the 19th century (Curry 1953; 1960). Commercial harvesting of the virgin timberlands of the UWGCP began in earnest by the 1880s when railroads were extended to most areas (Anonymous 1904; Balogh 1985), and continued relatively unabated for the next half-century (Fig. 11). Many lumber companies acquired their land holdings from local farmers, who were only too glad to get rid of their "worthless" timberlands (Morbeck 1915; Curry 1953; Buckner 1979; Reynolds 1980). Only the largest trees (those > 30 cm in stump diameter) in the virgin forest were initially considered desirable (Morbeck 1915; Mety 1952; Reynolds 1980). Fires were common in the slash and little effort was taken to protect the remaining forest.

Scientifically-based forestry was virtually unknown at the turn of the 20th century in America, so lumber companies exploited the forests until exhausted, then moved on or closed permanently (Curry 1953; Reynolds 1980; Shipley 1987). For example, the Crossett Lumber Company had no intention of engaging in forest management until the late 1920s when it became apparent that their attempts to promote their cut-over lands as agricultural and pastoral properties would not succeed (Reynolds 1980). By 1922 only about 16,200 hectares of the company's original 101,000 hectares contained virgin timber, but it was 1928 before cutting was reduced to prolong the harvest of the remaining timber (Curry 1953). The recognition of timber shortages and expansion of professional forestry eventually induced some of the remaining timber companies to manage for sustained production. Effective fire suppression was implemented in most of UWGCP by the mid-1930s (Mety 1952; Reynolds 1980). Fire exclusion further altered the natural dynamics of the region's pine-dominated forests, contributing noticeably to fuel accumulation, expansion of hardwoods, brush, and vines, and altered pine regeneration success (Chapman 1942; 1952). In the intervening decades, many natural upland stands have been converted to plantations, and landscapes have been continually fragmented.

Considerations and Cautions of Using Historical Documentation. Significant ecological change during the past two centuries of settlement, fire exclusion, forest management, and landscape development suggests that current fragments of old-growth stands are inadequate examples of presettlement conditions. Additionally, contemporary reference sites are often too small to provide the appropriate spatiotemporal context, or may be the product of an historic but rare event atypical of the desired ecological state (White and Walker 1997). Judging from this review on old-growth pine forests in the UWGCP, constructive information for ecosystem restoration can be gained from the assemblage of historical documents, photographs, and inventories. Even though not all areas have such a wealth of such documentation on early forest conditions, the presettlement conditions for many locations can be better described through this approach than from the examination of remnant stands.

Those involved in restoring presettlement conditions should first spend as much time as possible reviewing historical sources before modifying existing communities. This is true even if the information is limited to qualitative descriptions or period photographs, as these sources can at least define reasonable boundaries (Egan and Howell 2001). However, the use of historical references is not without challenges. Sources of quantitative data, such as timber inventories, may date back to target periods, but can be short on detail regarding minor or noncommercial taxa. Historical research reports or inventories rarely provide more than basic summaries, but are still highly relevant sources if available.

Be careful not to over-analyze historical data that were not collected specifically for ecological purposes, for this may lead to improper assumptions on reference conditions. The early GLO surveys, though an important window to presettlement vegetation patterns, have often been inappropriately interpreted (Whitney and DeCant 2001). For example, surveyors were instructed to select witness or marker trees that they felt had the best chance of long-term survival (Stewart 1935; Bureau of Land Management 1947), and thus may not reflect either the size class or compositional distribution of the stand in which they were chosen (Bourdo 1956).

Inaccurate descriptions can often be found in colloquial accounts of vegetation, as many early observers would comment on species with which they were unfamiliar, or described conditions with unscientific zeal. Some early trade journal articles consistently refer to the pine forests in their photographs as shortleaf, even though loblolly was obviously present (e.g., Anonymous 1904a,b; see also Morbeck 1915). This usage of "shortleaf" was probably meant to differentiate *Pinus taeda* and *P. echinata* from *P. palustris* (true longleaf pine). Blatantly incorrect material also occasionally appears in scientific or technical accounts. For example, an early paper by Professor F.L. Harvey reported that the botanist Thomas Nuttall had identified two pine species (*P. rigida* Mill. and *P. inops* Ait.) in Arkansas (Harvey 1883), neither of which naturally occurs anywhere near the state.

Conclusions. Once the objectives of the restoration have been identified, developing reference conditions for the area to be reconstructed is a critical first step in designing an effective restoration program. To do this, one must become familiar with the history and documentation of the area of interest (Egan and Howell 2001). Records from the pioneering efforts of GLO surveyors and those seeking to bring scientific forestry to the South also proved invaluable, and even the photographs and personal observations of early settlers have contributed to this effort. Although many sources of information were strictly qualitative, enough quantitative data could also be gleaned to produce a list of specific management targets. For instance, data on species, size class, and tree density distributions were readily available for virgin pine forests of the UWGCP. More valuable information was thus gathered than could be gained from the structural analysis of any existing research natural area or demonstration forest.

This effort allows those interested in the reconstruction of historical conditions to envision what virgin pine forests of the UWGCP were like before Euroamerican settlement. Using these historical sources as a guide, the virgin pine forests often appeared as open stands, with extensive grass and forb understories only occasionally interrupted by clumps of shrubs and tree saplings. Overstories in most upland pine stands were dominated by irregularly scattered shortleaf and loblolly pines. Nearby locations with better site quality have increasing levels of mature oak, hickory, and gum, with scattered supercanopy pine. Frequently, these isolated overstory pines were very large and centuries old, frequently fire-scarred, with twisted crowns, smooth bark, and abundant heart rot. Large twisted piles of downed trees covered in vines and briars provided further evidence of the natural catastrophes that periodically swept down upon the virgin pine forest of the UWGCP. Pine regeneration, when not destroyed by frequent surface fires, was thick in exposed mineral soil. Even-aged patches of young and maturing pine arose from the gaps formed by windthrow, beetle outbreaks, fires, or ice storms. The juxtapositioning of young, mature, and veteran timber over much of the landscape left the impression of an uneven-aged landscape, with multiple tiers of crowns. Red-cockaded woodpeckers were common visitors to the decadent old pines, and elk and perhaps even bison joined the white-tailed deer to graze the available forage.

While it may not prove possible to extensively reconstruct the virgin pine forests of the UWGCP on a large scale, understanding the range of variation, dynamics, and uniqueness of virgin forests should improve restoration efforts like those being attempted on the Gulf Coastal Plain of southern Arkansas.

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